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| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 10/751,349 | 01/05/2004 | Kirkland D. Broach | ARF 2004-003 | 2219 |

7590 09/23/2004

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Monroeville, PA 15146

| EXAMINER | |
|---|---|
| GREENE JR, DANIEL LAWSON | |

| ART UNIT | PAPER NUMBER |
|---|---|
| 3641 | |

DATE MAILED: 09/23/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 10/751,349 | BROACH ET AL. | |
| | Examiner | Art Unit | |
| | Daniel L Greene Jr. | 3641 | MW |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on *05 January 2004*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *1-17* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-17* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *05 January 2004* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *1/5/04*.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application (PTO-152)

6) ☐ Other: _____.

### *Information Disclosure Statement*

1. An initialed and dated copy of Applicant's IDS form 1449 received 1/5/2004 is attached to the instant Office action.

### *Specification*

2. The abstract of the disclosure is objected to because the last sentence lacks antecedent basis. The phrase "...the double chamfered inlet." should read "...a double chamfered inlet." Correction is required. See MPEP § 608.01(b).

### *Claim Objections*

3. A series of singular dependent claims is permissible in which a dependent claim refers to a preceding claim which, in turn, refers to another preceding claim.

Claim 17, which depends from dependent claim 4, should not be separated by any claim, which does not also depend from said dependent claim. It should be kept in mind that a dependent claim may refer to any preceding independent claim. In general, applicant's sequence will not be changed. See MPEP § 608.01(n).

### *Claim Rejections - 35 USC § 102*

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

**4. Claims 1 and 7-12 are rejected under 35 U.S.C. 102(b) as being clearly anticipated by U.S. Patent 4,900,507 to Shallenberger et al. hereafter Shallenberger.**

Shallenberger clearly discloses claim 1, a fuel assembly (10) for a nuclear reactor including a plurality of elongated nuclear fuel rods (22) having an extended axial length, at least a lowermost grid (20) supporting said fuel rods (22) in an organized array and having unoccupied spaces (52) defined therein adapted to allow flow of fluid coolant there through and past said fuel rods (22) when said fuel assembly (10) is installed in the nuclear reactor and a plurality of guide thimbles (18) extending along said fuel rods (22) through and supporting said grid (20), a debris filter bottom nozzle (12) disposed below said grid (20), below lower ends of said fuel rods (22), supporting said guide thimbles (18) and adapted to allow flow of fluid coolant into said fuel assembly (10), said debris filter bottom nozzle (12) comprising a substantially horizontal plate (46) extending substantially transverse to the axis of the fuel rods (22) and having an upper face directed toward said lowermost grid (20), said upper face of said plate (46) having defined there through at least two different types of holes, the first type being a plurality of holes (66) receiving lower ends of said guide thimbles (18) where they are supported by said plate (46) and the second type being a plurality of flow through holes (48) extending completely through said plate (46) for the passage of coolant fluid from a lower face of said plate to the upper face of said plate, each of said coolant flow through holes (48) extending substantially in the axial direction of said fuel rods (22), in fluid communication with said unoccupied spaces (52), and in the extended

direction at least some of said coolant flow through holes (48) having a profile substantially of a venturi, in Figures 1-10 and column 3 lines 24-54 and 67+, and columns 4-6. Wherein it is understood that in its most basic form, a venturi is nothing more than a short tube with a tapering constriction that causes an increase in the velocity of flow of a fluid and a corresponding decrease in fluid pressure.

Claim 7 is clearly disclosed in column 8 lines 2-26.

Claim 8 is clearly disclosed in Fig 1 and column 5 lines 1-6

Claim 9 is clearly disclosed in Figures 3 and 6.

Claims 10 and 11 are clearly disclosed in column 8 lines 2-5.

Claim 12 is clearly disclosed in the rejection of corresponding parts above.

### *Claim Rejections - 35 USC § 103*

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

**5. Claim 2 is rejected under 35 U.S.C. 103(a) as being unpatentable over Shallenberger in view of either the Mechanical Engineering Handbook, CRC Press LLC, ©1999 or the Industrial Burners Handbook, CRC Press LLC ©2003.**

Shallenberger discloses Applicant's invention substantially as claimed and described above, however Shallenberger does not disclose that the flow through holes (48) include a chamfer on the outlet end.

Fluid Mechanics in Chapter 3 of the Mechanical Engineer's Handbook, CRC Press LLC ©1999 teaches on page 3-190 that a conical diffuser section downstream from the throat of a venturi gives excellent pressure recovery.

Chapter 3 Fluid Flow of the Industrial Burners Handbook, CRC Press LLC ©2003 also teaches in Figure 3.3 and section 3.3.3 that a conical diffuser section downstream of the throat of a venturi provides a transition to the downstream section and that typically this section is designed with small transition angles to provide smooth flow in order to reduce pressure losses.

Both of these references are analogous art because they deal with the specific geometries and principles of venturis.

At the time of the invention it would have been obvious to a person of ordinary skill in the art to provide a chamfer on the outlet of the flow through holes in order to further reduce pressure losses and provide smoother flow downstream as such results are no more than basic mechanical principles of fluid flow dynamics available within the art.

**6. Claims 3, 4, 6 and 13-17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Shallenberger as modified by either the Mechanical Engineering Handbook, CRC Press LLC, ©1999 or the Industrial Burners Handbook, CRC Press LLC ©2003 and further in view of the Mechanical Engineering Handbook, SIXTH EDITION, McGRAW-HILL BOOK COMPANY, INC, ©1958.**

With regard to claims 3, 4, and 13-16, Shallenberger discloses Applicant's invention as modified above, however Shallenberger as modified above does not disclose that the flow through holes (48) include a double angle chamfer on the inlet end.

Chapter 3 pages 59-65 of the Mechanical Engineering Handbook, SIXTH EDITION, McGRAW-HILL BOOK COMPANY, INC, ©1958 also teach fluid flow through venturi's and orifices and that beveling the sharp upstream edge, even slightly, increases the discharge of an orifice. (see page 3-64 Rounding) Rounding the inlet edge of an orifice can obviously take many forms (Fig. 6), from multiple angle bevels, to rounding. In the case of a rounded edge, it is understood that the inlet angle would be comprised of an infinite number of chamfer angles, including those proposed by applicant.

As stated before, this reference is analogous art because it is teaching the principles of fluid flow through venturi's and orifices.

At the time of the invention it would have been obvious to a person of ordinary skill in the art to optimize the flow characteristics of the inlet of the flow holes by increasing the bevel with a double edge chamfer as well as a double angle chamfer approximating a curved surface in order to increase the discharge of the orifice as such results are no more than optimization of the previous art as Applicant's disclosure states on page 2 lines 3 and page 8 lines 5-7 by using old and well known basic mechanical principles of fluid flow dynamics available within the art.

Claims 6 and 17 are disclosed in The Mechanical Engineer's Handbook SIXTH EDITION, McGRAW-HILL BOOK COMPANY, INC, ©1958 section 3 pages 59 – 65, wherein it is apparent Applicant has translated/converted the table of claim 5 into mathematical equations stemming from typical venturi and orifice geometric relationships. As such, applicants table and values are no more than standard mechanical properties/geometric relationships available within the art.

See MPEP 2114.05 II "Where the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges by routine experimentation." "The normal desire of scientists or artisans to improve upon what is already generally known provides the motivation to determine where in a disclosed set of percentage ranges is the optimum combination of percentages." *In re Aller*, 220 F.2d 454, 456, 105 USPQ 233,235 (CCPA 1955) and *In re Hoeschelle* 406 F.2d 1403, 160 USPQ 809 (CCPA 1969)

7. **Claim 5 is rejected under 35 U.S.C. 103(a) as being unpatentable over Shallenberger as previously modified by either the Mechanical Engineering Handbook, CRC Press LLC, ©1999 or the Industrial Burners Handbook, CRC Press LLC ©2003 and the Mechanical Engineering Handbook, SIXTH EDITION, McGRAW-HILL BOOK COMPANY, INC, ©1958 and further in view of Chapter 42 Fluid Measurements of The Engineering Handbook, CRC Press LLC, ©2000**

Shallenberger as modified above further discloses an inlet chamfer angle of 12 to 15 degrees in column 8, claim 3 lines 27-29, however Shallenberger as modified does not expressly disclose the chamfer angle of the outlet of the flow through hole.

As previously discussed, the "inlet chamfer A" falls within the range in the rejection of corresponding parts of section 6 above.

Figure 42.6 Venturi Tube teaches that the diffuser section (outlet chamfer C) of a venturi may have an angle range of 5-15 degrees.

At the time of the invention it would have been obvious to a person of ordinary skill in the art to optimize the flow characteristics of the inlet and outlet of the flow holes in order to increase the discharge flow rate while decrease the pressure loss of the orifice as such results are no more than standard practices and well known basic mechanical principles of fluid flow dynamics available within the art.

See MPEP 2131.03 II Anticipation of Ranges, 2144.05 Obviousness of Ranges as well as MPEP 2114.05 II "Where the general conditions of a claim are disclosed in the prior art, it is not inventive to discover the optimum or workable ranges by routine experimentation." "The normal desire of scientists or artisans to improve upon what is already generally known provides the motivation to determine where in a disclosed set of percentage ranges is the optimum combination of percentages." *In re Aller*, 220 F.2d 454, 456, 105 USPQ 233,235 (CCPA 1955) and *In re Hoeschelle* 406 F.2d 1403, 160 USPQ 809 (CCPA 1969)

## *Conclusion*

8. The prior art made of record and not relied upon is considered pertinent to the state of the art in applicant's disclosure.

U.S Patent 5,009,839 to King discloses chamfered inlets and positions of coolant openings biased towards the inlet openings of the core plate.

The following U.S. Patents also disclose venturi and/or chamfered inlet and/or outlet flow through openings:

5,748,694; 5,094,802; 5,438,598; 5,024,806; 5,519,745

The following documents also disclose venturi and flow straighteners:

U.S. Patents 5,071,617, 3,840,051 and 3 Articles by M. Mitchell discussing the Bernoulli's Principle.

9. Examiner's Note: Examiner has cited particular columns and line numbers in the references as applied to the claims above for the convenience of the applicant. Although the specified citations are representative of the teachings in the art and are applied to the specific limitations within the individual claim, other passages and figures may apply as well. It is respectfully requested from the applicant, in preparing the responses, to fully consider the references in entirety as potentially teaching all or part of the claimed invention, as well as the context of the passage as taught by the prior art or disclosed by the examiner.

10. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Daniel L Greene Jr. whose telephone number is (703) 605-1210. The examiner can normally be reached on Mon-Fri 8:30am - 5pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Michael J Carone can be reached on (703) 306-4198. The fax phone

number for the organization where this application or proceeding is assigned is 703-872-9306.

11. Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

DIG 9/17/2004

MICHAEL J. CARONE
SUPERVISORY PATENT EXAMINER

A

# United States Patent [19]

**Shallenberger et al.**

[11] **Patent Number: 4,900,507**

[45] **Date of Patent: Feb. 13, 1990**

[54] **NUCLEAR FUEL ASSEMBLY DEBRIS FILTER BOTTOM NOZZLE**


[75] Inventors: **John M. Shallenberger; Stephen J. Ferlan**, both of Pittsburgh, Pa.

[73] Assignee: **Westinghouse Electric Corp.**, Pittsburgh, Pa.



[21] Appl. No.: **211,150**

[22] Filed: **Jun. 22, 1988**

**Related U.S. Application Data**

[63] Continuation of Ser. No. 46,219, May 5, 1987, abandoned.

[51] **Int. Cl.**[4] ........................ G21C 19/30; G21C 15/06

[52] **U.S. Cl.** .................................... 376/352; 376/313; 376/434; 376/443

[58] **Field of Search** ............... 376/352, 353, 362, 364, 376/365, 313, 438, 439, 434, 443


[56] **References Cited**


U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 2,938,848 | 5/1960 | Ladd et al. | 376/352 |
| 3,725,199 | 4/1973 | Notari et al. | 376/352 |
| 3,801,453 | 4/1974 | Jones | 176/78 |
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| 4,076,586 | 2/1978 | Bideau et al. | 176/78 |
| 4,096,032 | 6/1978 | Mayers et al. | 176/38 |
| 4,309,251 | 1/1982 | Anthony et al. | 376/364 |
| 4,323,428 | 4/1982 | Schallenberger et al. | 376/353 |
| 4,427,624 | 1/1984 | Marlatt et al. | 376/352 |
| 4,560,532 | 12/1985 | Barry et al. | 376/445 |
| 4,615,862 | 10/1986 | Huckestein | 376/362 |
| 4,678,627 | 7/1987 | Rylatt | 376/313 |
| 4,684,495 | 8/1987 | Wilson et al. | 376/364 |
| 4,781,884 | 11/1988 | Anthony | 376/313 |

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
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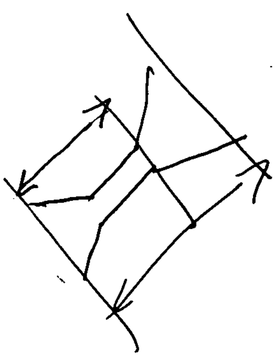
| 4141989 | 11/1979 | Japan | 376/352 |
| 0784890 | 12/1980 | U.S.S.R. | 210/521 |
| 0028977 | of 1906 | United Kingdom | 210/521 |


*Primary Examiner*—Harvey E. Dehrend


[57] **ABSTRACT**

A debris filter bottom nozzle in a fuel assembly has support structure in the form of four legs adapted to rest on a lower core plate of the nuclear reactor and a nozzle plate fixed one side of the four legs facing toward a lowermost grid of the fuel assembly. The nozzle plate has defined therethrough only a plurality of flow holes individually smaller in size than the maximum dimension of unoccupied spaces through the lowermost grid which allow flow of liquid coolant through the nozzle plate. Therefore, any debris being carried by the liquid coolant flowing through the bottom nozzle from the lower core plate to the fuel assembly which is small enough in size to pass through the flow holes will also pass through the unoccupied grid spaces, whereas any debris which is large enough to not pass through the unoccupied grid spaces and collect in the grid will not pass through the aperture plate flow holes.


**6 Claims, 4 Drawing Sheets**



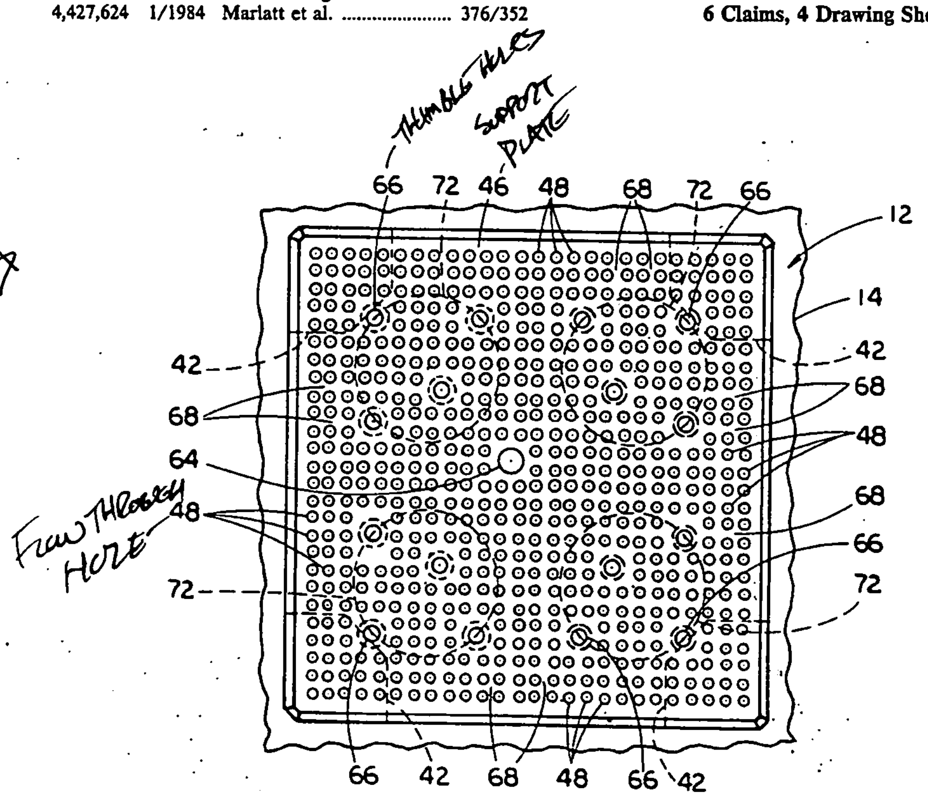
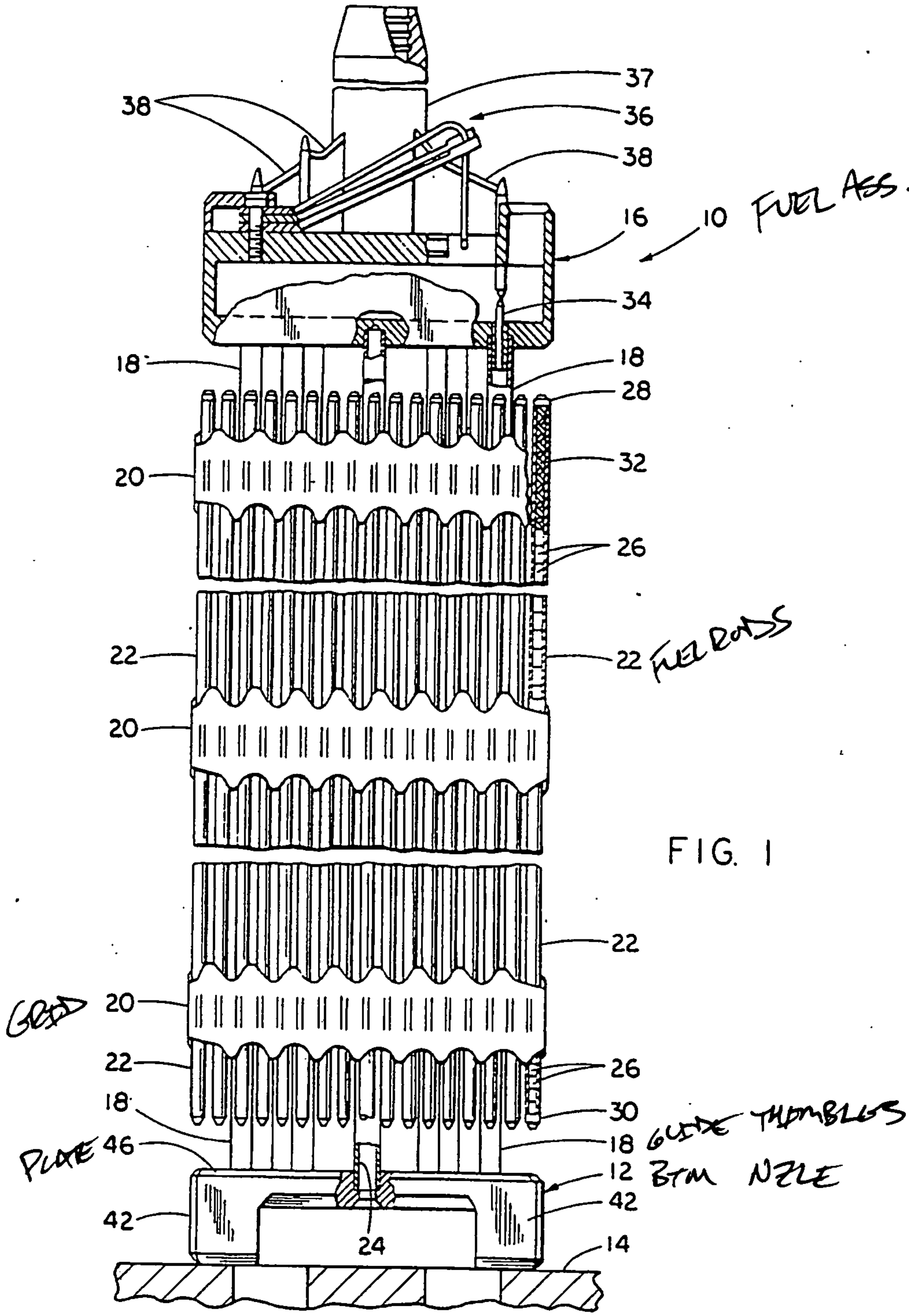



FIG 7.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18 GUIDE THIMBLES
PLATE 46
12 BTM NZLE
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FIG. 1

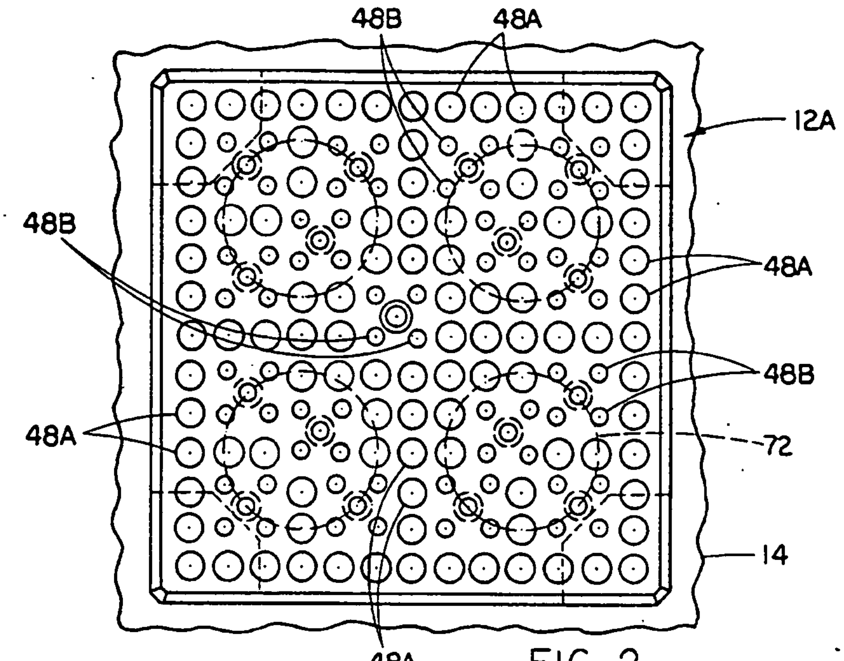


FIG. 2
(PRIOR ART)

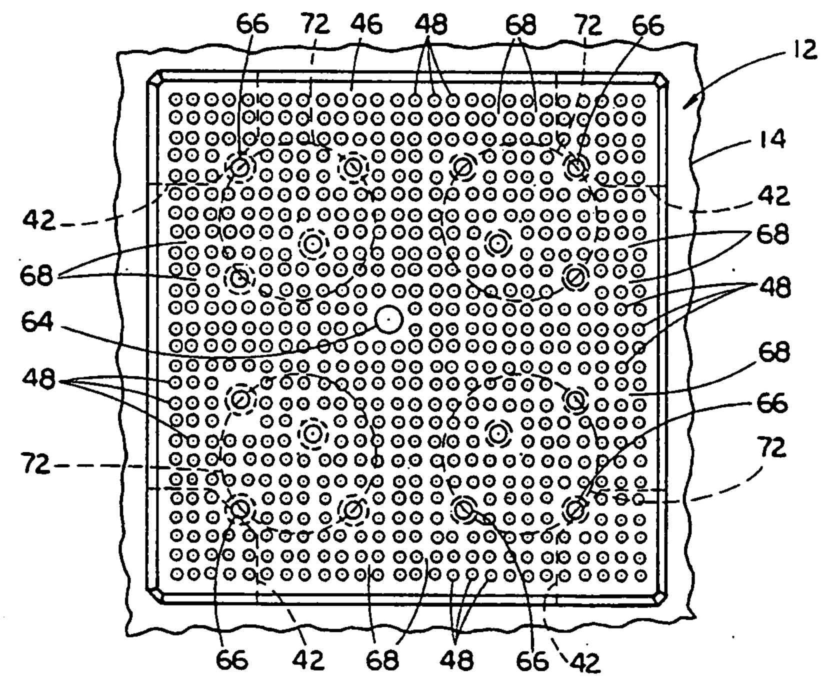


FIG. 3

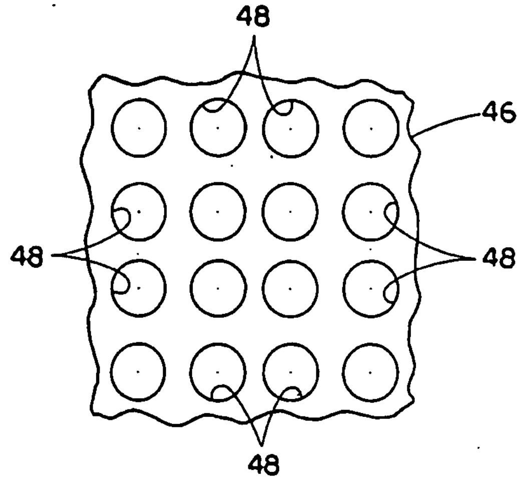


FIG. 4

UNOCCUPIED SPACES

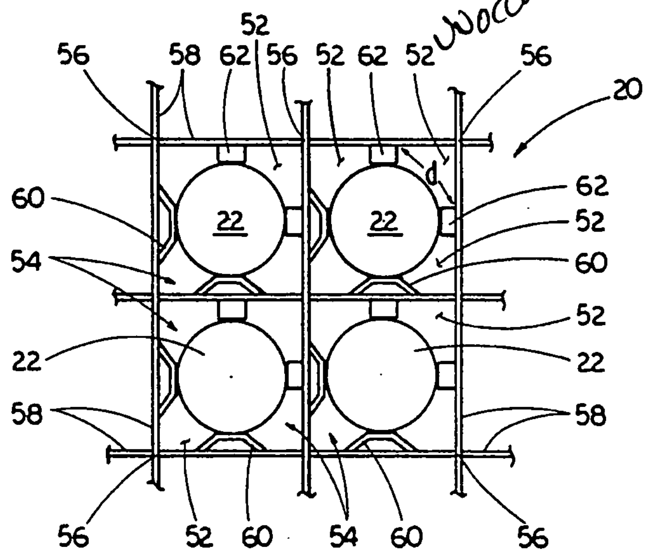


FIG. 5

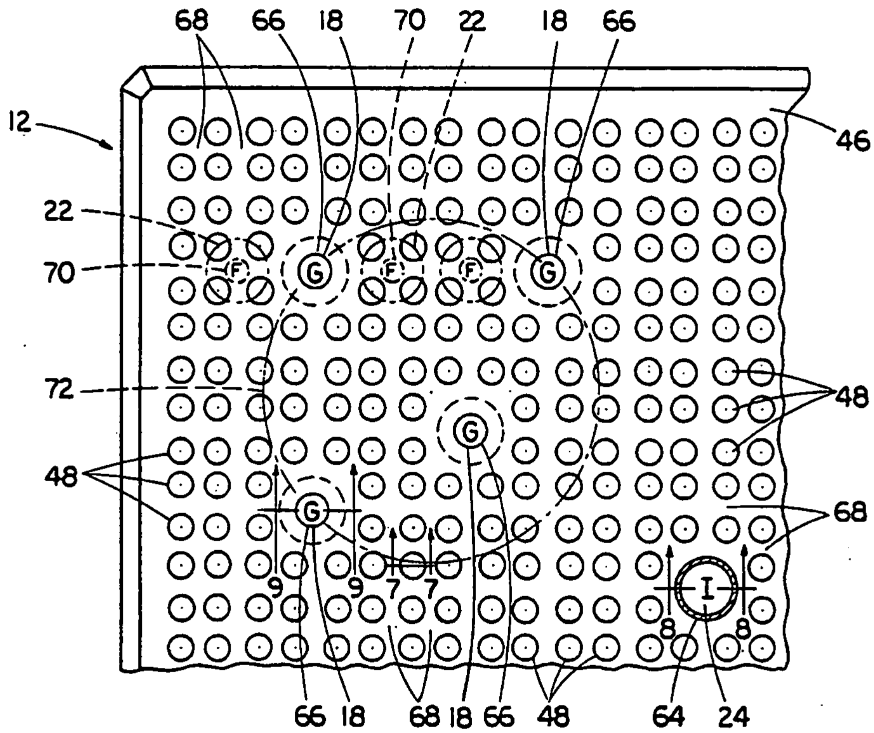


FIG. 6

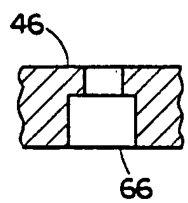


FIG. 9

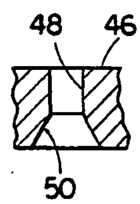


FIG. 7

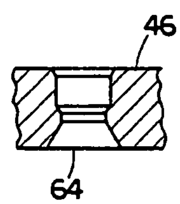


FIG. 8

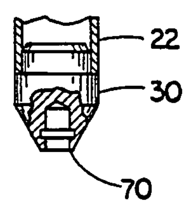


FIG. 10

# NUCLEAR FUEL ASSEMBLY DEBRIS FILTER BOTTOM NOZZLE

## CROSS REFERENCE TO RELATED APPLICATIONS

Reference is hereby made to the following copending patent applications dealing with related subject matter and assigned to the assignee of the present invention:

1. "Debris Trap For A Pressurized Water Nuclear Reactor" by John F. Wilson et al, assigned U.S. Ser. No. 672,040 and filed Nov. 16, 1984. (W.E. No. 52,222) now U.S. Pat. No. 4,684,496, issued Aug. 4, 1987.

2. "Fuel Assembly Bottom Nozzle With Integral Debris Trap" by John F. Wilson et al, assigned U.S. Ser. No. 672,041 and filed Nov. 16, 1984. (W.E. No. 52,223) now U.S. Pat. No. 4,684,495, issued Aug. 4, 1987.

3. "Wire Mesh Debris Trap For A Fuel Assembly" by William Bryan, assigned U.S. Ser. No. 679,511 and filed Dec. 7, 1984. (W.E. No. 52,287) now U.S. Pat. No. 4,664,880, issued May 12, 1987.

4. "Debris-Retaining Trap For A Fuel Assembly" by John A. Rylatt, assigned U.S. Ser. No. 720,109 and filed Apr. 4, 1985. (W.E. No. 52,484) now U.S. Pat. No. 4,678,627, issued July 7, 1987.

5. "Bottom Grid Mounted Debris Trap For A Fuel Assembly" by Harry M. Ferrari et al, assigned U.S. Ser. No. 763,737 and filed Aug. 8, 1985. (W.E. No. 2,803) now U.S. Pat. No. 4,652,425, issued Mar. 24, 1987.

This application is a continuation of application Ser. No. 046,219, filed May 5, 1987, now abandoned.

## BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION

The present invention relates generally to nuclear reactors and, more particularly, is concerned with a debris filter bottom nozzle in a nuclear fuel assembly.

### DESCRIPTION OF THE PRIOR ART

During manufacture and subsequent installation and repair of components comprising a nuclear reactor coolant circulation system, diligent effort is made to help assure removal of all debris from the reactor vessel and its associated systems which circulate coolant therethrough under various operating conditions. Although elaborate procedures are carried out to help assure debris removal, experience shows that in spite of the safeguards used to effect such removal, some chips and metal particles still remain hidden in the systems. Most of the debris consists of metal turnings which were probably left in the primary system after steam generator repair or replacement.

In particular, fuel assembly damage due to debris trapped at the lowermost grid has been noted in several reactors in recent years. Debris enters through the fuel assembly bottom nozzle flow holes from the coolant flow openings in the lower core support plate when the plant is started up. The debris tends to become lodged in the lowermost support grid of the fuel assembly within the spaces between the "egg-crate" shaped cell walls of the grid and the lower end portions of the fuel rod tubes. The damage consists of fuel rod tube perforations caused by fretting of debris in contact with the exterior of the tube. Debris also becomes entangled in the nozzle plate holes and the flowing coolant causes the debris to



gyrate which tends to cut through the cladding of the fuel rods

Several different approaches have been proposed and tried for carrying out removal of debris from nuclear reactors Many of these approaches are discussed in U.S. Pat. No. 4,096,032 to Mayers et al. Others are illustrated and described in the U. S. patent applications cross-referenced above. While all of the approaches described in the cited patent and patent applications operate reasonably well and generally achieve their objectives under the range of operating conditions for which they were designed, a need still exists for a fresh approach to the problem of debris filtering in nuclear reactors. The new approach must be compatiable with the existing structure and operation of the components of the reactor, be effective throughout the operating cycle of the reactor, and at least provide overall benefits which outweigh the costs it adds to the reactor.

## SUMMARY OF THE INVENTION

The present invention provides a debris filter bottom nozzle in a fuel assembly designed to satisfy the aforementioned needs. The bottom nozzle of the present invention includes a nozzle plate employing the concept of having flow holes smaller in diameter than used heretofore and of an increased number as well as smaller than the unoccupied spaces through the lowermost grid. The flow holes are preferably about 0.190 inch in diameter which makes them sized to filter out debris of damage-inducing size which otherwise collects primarily in the sections between the bottom nozzle and the lowermost grid and in the unoccupied spaces of the lowermost grid and causes fuel rod fretting failures. Unexpectedly, this concept reduces pressure drop of the debris filter bottom nozzle as compared to the prior art bottom nozzle although the total flow area through the bottom nozzle of the present invention is less than the total flow area through the prior art bottom nozzle. Significantly greater flow area is provided by the debris filter bottom nozzle pattern of smaller flow holes than by the prior art bottom nozzle pattern of larger flow holes in the local areas of the respective nozzle plates directly above the coolant inlet flow holes in the reactor lower core plate.

Accordingly, the present invention is directed to a debris filter bottom nozzle useful in a fuel assembly for a nuclear reactor wherein the fuel assembly includes a plurality of nuclear fuel rods, at least a lowermost grid supporting the fuel rods in an organized array and having unoccupied spaces defined therein allowing flow of liquid coolant therethrough. The debris filter bottom nozzle is disposed adjacent to and below the grid and below lower ends of the fuel rods. The bottom nozzle comprises: (a) support means adapted to rest on a lower core plate of the nuclear reactor; and (b) a nozzle plate fixed on the support means facing toward the lowermost grid and having defined therethrough only a plurality of flow apertures individually smaller in size than the maximum dimension of the unoccupied spaces through the lowermost grid which allow flow of liquid coolant through the nozzle plate such that any debris being carried by the liquid coolant which is small enough to pass through the flow apertures will also pass through the unoccupied grid spaces, whereas any debris being carried by the liquid coolant which is large enough to not pass through the unoccupied grid spaces and collect in the grid will not pass through the flow apertures.

More particularly, the flow aperatures are in the form of circular holes and uniform in cross-sectional size. Preferably, the flow holes are about 0.190 inch or less in diameter and are packed in a density of about 16 per square inch. Preferably, the holes are 0.190 +/−0.008 inch in diameter. The ligaments or sections of the nozzle plate extending between the flow holes have a maximum dimension of one-tenth inch. Further, the flow holes each have a long taper inlet chamfer of about 0.140 inch in length and forming an angle of about 12 to 15 degrees to a central axis of said hole. Still further, preferably the majority of flow holes are defined through the nozzle plate at locations directly above the inlet flow openings of the lower core plate.

These and other advantages and attainments of the present invention will become apparent to those skilled in the art upon a reading of the following detailed description when taken in conjunction with the drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the course of the preceding discussion and following detailed description, reference has been and will be made to the attached drawings in which:

FIG. 1 is an elevational view, partly in section, of a fuel assembly which incorporates the debris filter bottom nozzle of the present invention, the assembly being illustrated in vertically foreshortened form with parts broken away for clarity.

FIG. 2 is a top plan view of a prior art bottom nozzle showing the pattern of large diameter size flow holes in its plate.

FIG. 3 is an enlarged top plan view of the debris filter bottom nozzle of the fuel assembly of FIG. 1, showing the pattern of small diameter size flow holes in its plate.

FIG. 4 is an enlarged top plan view of a fragmentary portion of the plate of the debris filter bottom nozzle of FIG. 3.

FIG. 5 is an enlarged bottom plan view of a fragmentary portion of the lowermost grid of the fuel assembly of the fuel assembly of FIG. 1.

FIG. 6 is an enlarged top plan view of the upper left hand corner of the debris filter bottom nozzle of FIG. 3.

FIG. 7 is an enlarged cross-sectional view of one of the flow holes in the debris bottom nozzle taken along line 7—7 of FIG. 6.

FIG. 8 is an enlarged cross-sectional view of the instrumentation tube hole in the debris filter bottom nozzle taken along line 8—8 of FIG. 6.

FIG. 9 is an enlarged cross-sectional view of one of the guide thimble holes in the debris filter bottom nozzle taken along line 9—9 of FIG. 6.

FIG. 10 is an enlarged fragmentary axial cross-sectional view of a lower end portion of one of the fuel rods in the fuel assembly of FIG. 1.

## DETAILED DESCRIPTION OF THE INVENTION

In the following description, like reference characters designate like or corresponding parts throughout the several views of the drawings. Also in the following description, it is to be understood that such terms as "forward", "rearward", "left", "right", "upwardly", "downwardly", and the like are words of convenience and are not to be construed as limiting terms.

### In General

Referring now to the drawings, and particularly to FIG. 1, there is shown an elevational view of a fuel assembly, represented in vertically foreshortened form and being generally designated by the numeral 10. The fuel assembly 10 is the type used in a pressurized water reactor and has a structural skeleton which at its lower end includes the debris filter bottom nozzle 12 of the present invention (which will be described later in detail). The bottom nozzle 12 supports the fuel assembly 10 on a lower core support plate 14 in the core region of a reactor (not shown). In addition to the bottom nozzle 12, the structural skeleton of the fuel assembly 10 also includes a top nozzle 16 at its upper end and a number of guide tubes or thimbles 18 which extend longitudinally between the bottom and top nozzles 12,16 and at opposite ends are rigidly attached thereto.

The fuel assembly 10 further includes a plurality of transverse grids 20 axially spaced along and mounted to the guide thimbles 18 and an organized array of elongated fuel rods 22 transversely spaced and supported by the grids 20. Also, the assembly 10 has an instrumentation tube 24 located in the center thereof and extending between and mounted to the bottom and top nozzles 12,16. With such an arrangement of parts, the fuel assembly 10 forms an integral unit capable of being conveniently handled without damaging the assembly parts.

As mentioned above, the fuel rods 22 in the array thereof in the assembly 10 are held in spaced relationship with one another by the grids 20 spaced along the fuel assembly length. Each fuel rod 22 includes nuclear fuel pellets 26 and is closed at its opposite ends by upper and lower end plugs 28,30. The pellets 26 are maintained in a stack thereof by a plenum spring 32 disposed between the upper end plug 28 and the top of the pellet stack. The fuel pellets 26 composed of fissile material are responsible for creating the reactive power of the reactor. A liquid moderator/coolant such as water, or water containing boron, is pumped upwardly through a plurality of flow openings in the lower core plate 14 to the fuel assembly. The bottom nozzle 12 of the fuel assembly 10 passes the coolant flow upwardly through the guide thimbles 18 and along the fuel rods 22 of the assembly in order to extract heat generated therein for the production of useful work.

To control the fission process, a number of control rods 34 are reciprocally movable in the guide thimbles 18 located at predetermined positions in the fuel assembly 10. Specifically, a rod cluster control mechanism 36 positioned above the top nozzle 16 supports the control rods 34. The control mechanism has an internally threaded cylindrical member 37 with a plurality of radially extending flukes or arms 38. Each arm 38 is interconnected to a control rod 34 such that the control mechanism 36 is operable to move the control rods vertically in the guide thimbles 18 to thereby control the fission process in the fuel assembly 10, all in a well-known manner.

### Debris Trap Bottom Nozzle

As mentioned above, fuel assembly damage due to debris trapped at or below the lowermost one of the grids 20 has been found to be a problem. Therefore, to prevent occurrence of such damage, it is highly desirable to prevent this debris from passing through the bottom nozzle flow holes.

The present invention relates to a bottom nozzle 12, which in addition to supporting the fuel assembly 10 on the lower core support plate 14, also contains features which function to filter out potentially damaging-size debris from the coolant flow passed upwardly through

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the bottom nozzle. The bottom nozzle 12 includes support means in the form of a plurality of corner legs 42 for supporting the fuel assembly 10 on the lower core plate 14 and a generally rectangular planar plate 46 suitably attached, such as by welding, to the corner legs 42. As seen in FIG. 2, the prior art bottom nozzle 12A has a plate 46A with a large number of relatively large flow holes 48A,48B of two different diameter sizes therein (for instance 0.25 and 0.50 inch). The flow holes 48A,48B are large enough in their respective diameters to pass the damaging-size debris typically carried in the coolant flow.

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In the nozzle plate 46 of the debris filter bottom nozzle 12 of the present invention, the prior art large flow holes 48A,48B have been replaced with an increased number of smaller holes 48, being sized to "filter out" damaging-size debris without adversely affecting flow or pressure drop through the adapter plate 46 and across the fuel assembly 10. The debris filter bottom nozzle 12 is similar to the prior art bottom nozzle 12A, except for the number and size of the flow holes 48 in the plate 46 and the size of the inlet chamfers 50 at each flow hole 48, as shown in FIG. 6. The flow holes 48 are preferably uniform in cross-sectional size and defined in a pattern which substantially covers every portion of the plate 46 across its length and breadth.

The diameter of the flow holes 48, as shown in a fragmentary enlarged view of the plate 46 in FIG. 4, does not allow passage of debris that is of the size typically caught in the lowermost support grid 20. If the debris is small enough to pass through these plate flow holes 48, it will also pass through the grids 20 since the diameter of the flow holes 48 is smaller than the largest cross-sectional dimension "d" of the unoccupied spaces 52 through a cell 54 of the support grid 20, being shown in FIG. 5. Such spaces 52 are typically found in adjacent corners 56 form by the interleaved straps 58 composing the grid 20 and are bounded by the corners 56, respective dimples 60 and spring 62 formed on the straps 58, and the fuel rods 22 which extend through the grid cells 54. By ensuring that the debris is small enough to pass through the grid spaces 52, the debris filter bottom nozzle 12 of the present invention thereby significantly reduces the potential for debris-induced fuel rod failures.

Based upon a comprehensive analysis of fuel surveillance underwater television photographs of fuel assemblies from reactors experiencing debris-induced fuel rod failures, a nominal diameter for the flow holes 48 of about 0.190 inch was selected (with 0.190 +/−0.008 inch being preferred). It is possible for the holes 48 to be made somewhat smaller in diameter also. All observed primary debris-induced fuel rod failures were at or below the lowermost grid and appeared to be caused by debris somewhat larger than 0.190 inch in width. Other smaller debris typically present in the reactor coolant systems is believed to be relatively delicate in nature and not likely to cause rod damage since little or no significant damage has been observed above the lowermost grid. The evidence suggest that heretofore the damaging-size debris is effectively stopped by the lowermost grid 20. The debris filter bottom nozzle 12 with approximately 0.190 inch diameter size flow holes 48 defined in its plate 46 is expected to reduce by 90 percent the potential rod-damaging metallic debris carried into fuel assemblies by the primary coolant flow. Such estimate may be conservative since it appears likely that debris substantially larger than 0.190 inch in width may do a disproportionate amount of fuel rod damage.



Referring now to FIGS. 6–10, it is seen that in addition to the large number of flow holes 48, the plate 46 includes one central instrumentation tube hole 64 and a number of guide thimble holes 66. As seen in FIG. 7, a long taper inlet chamfer 50, about 0.140 inch in length and forming an angle of about 12 to 15 degrees to the axis of the hole 48, is employed on each of the flow holes 48 to optimize the flow, i.e., minimize the loss coefficient increase due to the higher frictional effect inherent with the smaller flow holes 48. The longer chamfers 50 will prevent the flow stream from reattaching within the adapter plate holes 48 and increasing pressure drop across the fuel assembly 10. Any increase in pressure drop across the fuel assembly with the debris filter bottom nozzle 12 compared to an assembly with the conventional bottom nozzle 12A would be undesirable and very likely unacceptable.

One addition conventional function of the bottom nozzle plate 46 is to capture the fuel rods 22, that is, to prevent them from dropping through the bottom nozzle 12. At initial startup, the fuel rods 22 are held by the grids 20 above the bottom nozzle 12, as seen in FIG. 1. However, after the reactor has operated for a time, the grids 20 commonly loosen their grip on the fuel rods 22 and some drop down on the top of the bottom nozzle plate 46. As seen in FIG. 6, the fuel rods 22 are aligned with the ligaments or sections 68 of the plate 46 between the flow holes 48. The flow holes 48 are packed in a density of about 16 per square inch. The sections 68 of the plate 46 extending between the flow holes 48 have a maximum dimension of 1/10 inch. If the fuel rods 22 having maximum diameters of about 0.400 inch were located over the flow holes 48, then when falling down on the plate 46 they would plug up the holes and cause an increase in pressure drop. The lower end plugs 30 of the fuel rods 22 which rest on sections 68 of the plate 46 have a terminal end diameter of about 0.150 inch and a tapered axial cross-sectional shape, as seen in FIG. 10, which does not block the holes 48. However, if the terminal end 70 of the lower end plug 30 was larger in diameter, then the section 68 of the plate 46 between the flow holes 48 would have to be larger in size in order to avoid the plug ends from covering portions of the adjacent holes 48. This would undoubtedly translate into fewer flow holes and an increase in pressure drop.

Flow testing of a fuel assembly incorporating the debris filter bottom nozzle 12 of the present invention unexpectedly identified a unique quality of it. Initially, the bottom nozzle 12 was designed to have a total flow area through a pattern of 0.190 inch flow holes in the plate equivalent to the total flow area through the pattern of the much larger holes 48A and 48B (approximately 0.25 and 0.50 inch diameters respectively) of the prior art bottom nozzle 12A of FIG. 2. It was believed that, at a minimum, matching the total flow areas and optimizing the inlet chamfers 50 in the smaller holes 48 would be necessary in order to keep the pressure drop close to that of the prior art bottom nozzle and to provide comparable flow. In the final design, the total flow area of the bottom nozzle of the present invention was slightly less than the total flow area of the prior art bottom nozzle. In the flow testing, however, although the flow area of the debris filter bottom nozzle 12 was less than that of the prior art bottom nozzle 12A, it was found that rather than obtaining the same or (as anticipated) a slightly higher pressure drop across the fuel

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assembly 10, the debris filter bottom nozzle 12 actually resulted in a 5% lower pressure drop than with the prior art bottom nozzle 12A.

An investigation into the cause of this unexpected lower pressure drop revealed that it was due to a 19% greater flow area in the debris filter bottom nozzle 12A in four local areas, each directly above the four inlet flow holes, identified by number 72 in FIGS. 2, 3 and 6, of the lower core plate 14 aligned with each fuel assembly. This discovery seems to show that increasing the flow area through the portions of the plate 46 directly above the core plate flow holes 72 is more beneficial in reducing pressure drop than is providing an equivalent total flow area uniformly through the entire plate.

Reduce Holes by concentrating over inlet core plate

Several potential benefits from use of the low pressure drop bottom nozzle 12 in fuel assembly design are expected to be realized. The number of flow holes in the bottom nozzle can possibly be reduced by concentrating a high density hole pattern directly over the inlet core plate holes 72, thereby optiminzing the design for flow, reducing the manufacturing costs, and reducing the stress levels on the bottom nozzle. The lower pressure drop attained with this bottom nozzle design will also allow use of other features in fuel assemblies, such as intermediate flow mixer grids and baffle-jetting anti-vibration grids or clips, which typically are not used widely because they raise the pressure drop. Also, LOCA and DNB penalties caused by high pressure drop resulting in lower total pump heads can be reduced, as can loads on the reactor vessel head caused by high pressure drop across the fuel assemblies.

It is thought that the present invention and many of its attendant advantages will be understood from the foregoing description and it will be apparent that various changes may be made in the form, construction and arrangement thereof without departing from the spirit and scope of the invention or sacrificing all of its material advantages, the forms hereinbefore described being merely a preferred or exemplary embodiment thereof.

We claim:

1. In a fuel assembly for a nuclear reactor, said fuel assembly including a plurality of nuclear fuel rods, at least a lowermost grid supporting said fuel rods in an organized array and having unoccupied spaces defined therein adapted to allow flow of liquid coolant therethrough and past said fuel rods when said fuel assembly is installed in the nuclear reactor, said spaces each having a predetermined maximum cross-sectional dimension lying in a plane extending transverse to the direction of liquid coolant flow through the spaces, an instrumentation tube extending along said fuel rods and through said grid, and a plurality of guide thimbles extending along said fuel rods through and supporting said grid, a debris filter bottom nozzle disposed adjacent to and below said grid, below lower ends of said fuel rods, supporting said guide thimbles and said instrumentation tube and adapted to allow flow of liquid coolant into said fuel assembly, said debris filter bottom nozzle comprising:

(a) support means adapted to support said fuel assembly when installed in the nuclear reactor; and

(b) a rigid plate fixed at its periphery on said support means and facing toward said lowermost grid, said plate having defined therethrough only three different types of holes, the first type being a plurality of non-flow holes receiving lower ends of said guide thimbles where they are attached to said plate, the second type being another non-flow hole receiving a lower end of said instrumentation tube where it is attached to said plate, and the third type being a plurality of circular flow holes all of which

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are packed in a density of about 16 per square inch and are individually 0.190+/−0.008 inch or less in

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diameter which is smaller than said predetermined maximum cross-sectional dimension of each of said unoccupied spaces through said lowermost grid, said plate also having sections extending between said flow holes of said third type which sections have a maximum dimension of one-tenth inch, said flow holes of said third type being the only holes of the three types allowing flow of liquid coolant through said plate and upwardly along said fuel rods and through said lowermost grid such that most debris being carried by the liquid coolant which is narrow enough in width to pass through said flow holes will also be capable of passing through said unoccupied grid spaces, whereas debris being carried by the liquid coolant which is wide enough to not pass through said unoccupied grid spaces and collect in said grid will not pass through said flow holes.

2. The bottom nozzle as recited in claim 1, wherein said holes each have a taper inlet chamfer of about 0.140 inch in length.

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3. The bottom nozzle as recited in claim 2, wherein said inlet chamfer forms an angle of about 12 to 15 degrees to the central axis of said hole.

4. In a nuclear reactor core including liquid coolant flowing upwardly through said core, a lower core support plate having inlet flow openings through which flows said liquid coolant, and a plurality of fuel assemblies resting on said lower core support plate, each said fuel assembly including a plurality of nuclear fuel rods, at least a lowermost grid supporting said fuel rods in an organized array and having unoccupied spaces defined therein adapted to allow flow of said liquid coolant therethrough and past said fuel rods, said spaces each having a predetermined maximum cross-sectional dimension lying in a plane extending transverse to the direction of liquid coolant flow through the spaces, an instrumentation tube extending along said fuel rods and through said grid, and a plurality of guide thimbles extending along said fuel rods through and supporting said grid, a debris filter bottom nozzle in each said fuel assembly being disposed above the inlet flow openings of the lower core support plate adjacent to and below said grid, below lower ends of said fuel rods, supporting said guide thimbles and said instrumentation tube and adapted to allow flow of liquid coolant into said fuel assembly, said debris filter bottom nozzle comprising:

(a) support means resting on said lower core plate of said nuclear reactor core; and

(b) a rigid plate fixed at its periphery on said support means and facing toward said lowermost grid, said plate having defined therethrough only three different types of holes, the first type being a plurality of non-flow holes receiving lower ends of said guide thimbles where they are attached to said plate, the second type being another non-flow hole receiving a lower end of said instrumentation tube where it is attached to said plate, and the third type being a plurality of circular flow holes all of which are packed in a density of about 16 per square inch and are individually 0.190 +/−0.008 inch or less in diameter which is smaller than said predetermined maximum cross-sectional dimension of each

of said unoccupied spaces through said lowermost grid, said plate also having sections extending between said flow holes of said third type which sections have a maximum dimension of one-tenth inch, said flow holes of said third type being the only holes of the three types allowing flow of liquid coolant through said plate and upwardly along said fuel rods and through said lowermost grid such that most debris being carried by the liquid coolant which is narrow enough in width to pass through said flow holes will also be capable of passing through said unoccupied grid spaces, whereas debris being carried by the liquid coolant which is wide enough to not pass through said unoccupied grid spaces and collect in said grid will not pass through said flow holes.

5. The bottom nozzle as recited in claim 4, wherein said holes each have a taper inlet chamfer of about 0.140 inch in length.

6. The bottom nozzle as recited in claim 5, wherein said inlet chamfer forms an angle of about 12 to 15 degrees to a central axis of said hole.

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# United States Patent [19]

**King**

[11] **Patent Number: 5,009,839**

[45] **Date of Patent: Apr. 23, 1991**

[54] **NUCLEAR FUEL ASSEMBLY BOTTOM NOZZLE PLATE**


[75] Inventor: **Raymond A. King, Lynchburg, Va.**

[73] Assignee: **B&W Fuel Company, Lynchburg, Va.**



[21] Appl. No.: **577,384**

[22] Filed: **Sep. 4, 1990**

[51] Int. Cl.[5] ........................ **G21C 19/30**; G21C 3/30; G21C 15/00

[52] U.S. Cl. .................................... **376/352**; 376/313; 376/443; 376/434; 376/446; 138/37; 138/44

[58] **Field of Search** ............... 376/352, 313, 443, 446; 138/37, 41, 44


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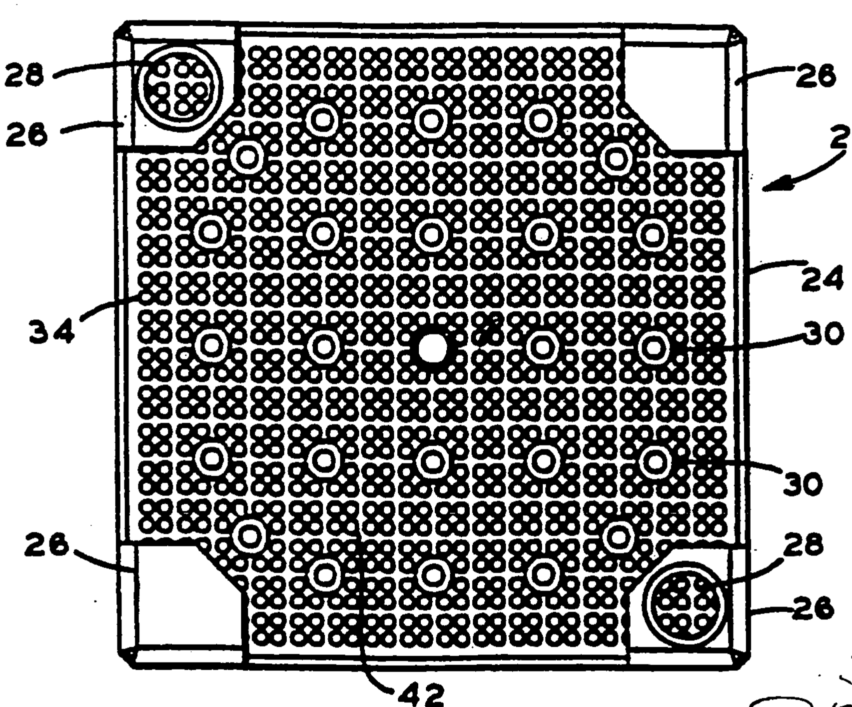
*Primary Examiner*—Brooks H. Hunt
*Assistant Examiner*—Frederick H. Voss
*Attorney, Agent, or Firm*—Robert J. Edwards; D. Neil LaHaye


[57] **ABSTRACT**


A bottom nozzle plate for a fuel assembly in a nuclear reactor. The bottom nozzle plate is formed from a rigid substantially square plate having legs adapted to be positioned on the lower core plate of the reactor for supporting the fuel assembly above coolant inlet openings in the core plate. The rigid square plate has two types of coolant flow holes therethrough. The first flow holes are grouped in clusters of four to define a square pattern relative to the sides of the plate such that the width of the sections of the plate between the flow holes in each cluster is less than the width of the sections of the plate between the clusters of four holes. Each of the second flow holes is formed in an irregular pattern to define a substantially clover leaf shape. The second flow holes are positioned so as to be above the coolant inlet openings in the core plate when the bottom nozzle plate is installed in the reactor.


**4 Claims, 4 Drawing Sheets**




Pos. Holes Above Coolant Openings

CHAMFERED INLET

FB 7

FIG. 1

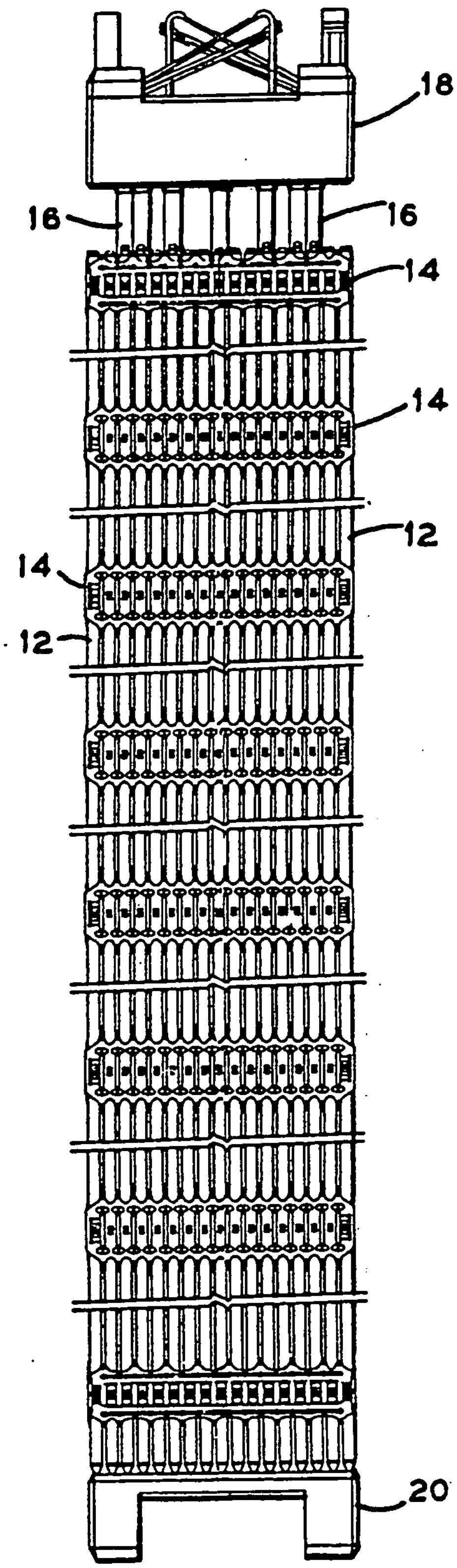


FIG. 2

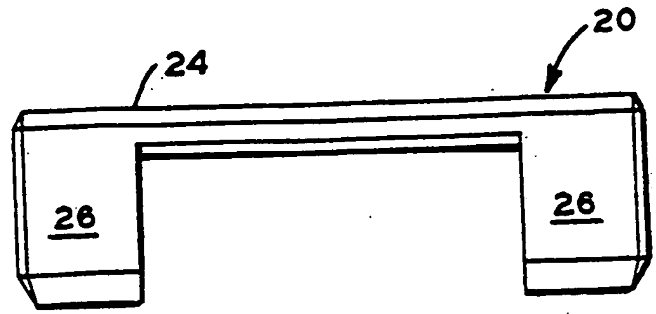



FIG. 3

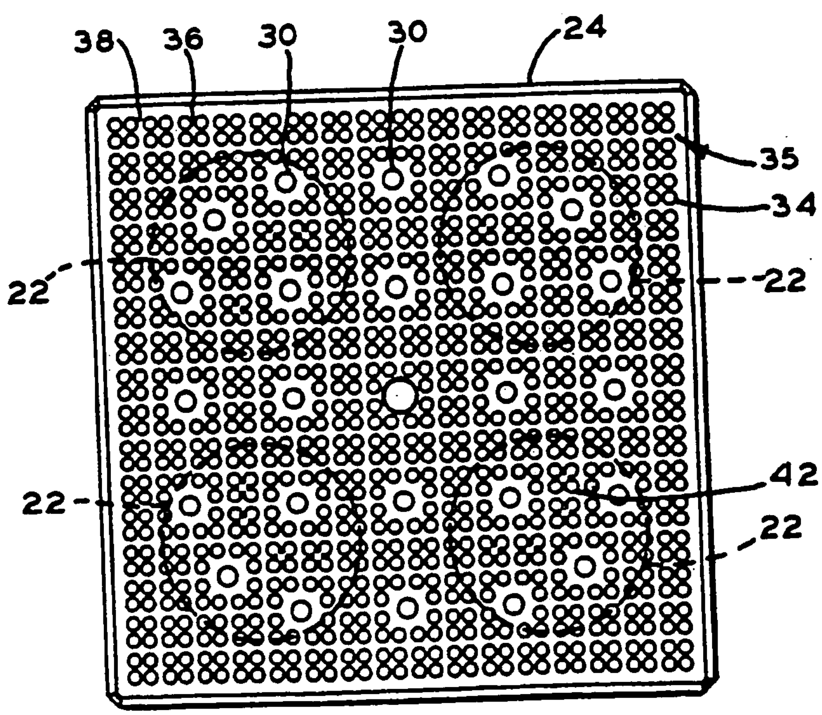


FIG. 4

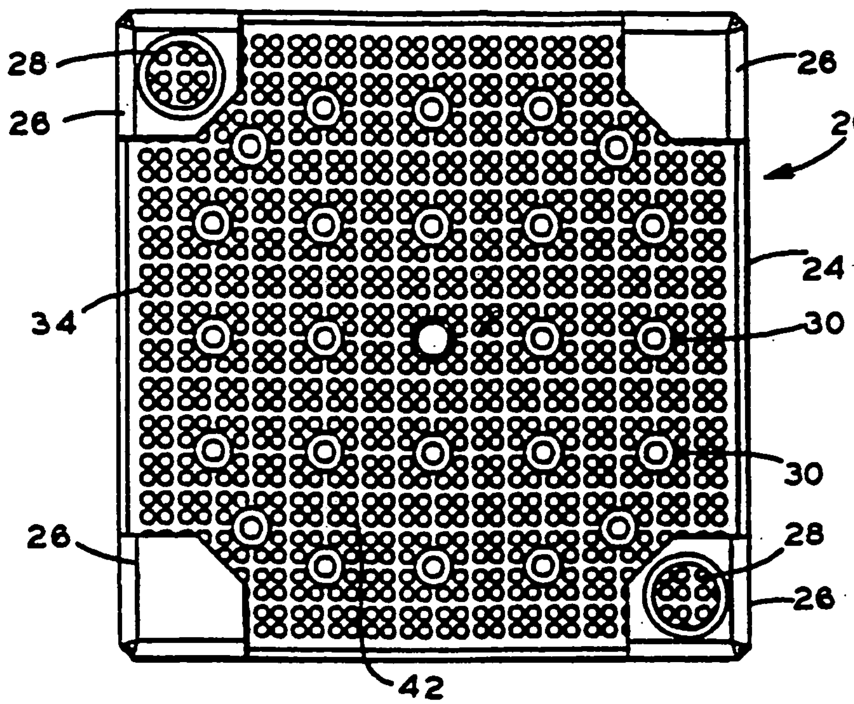



FIG. 5

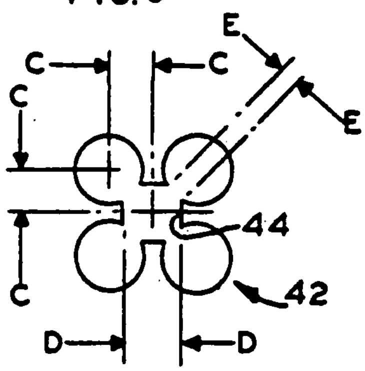



FIG. 6

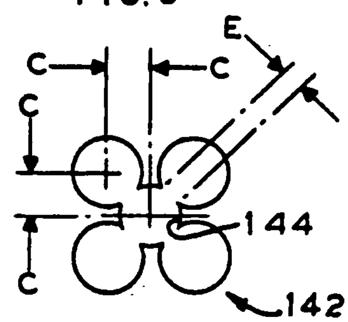



FIG. 7

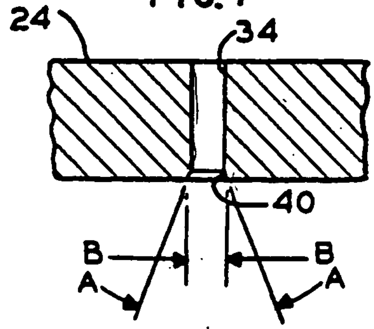


FIG. 8

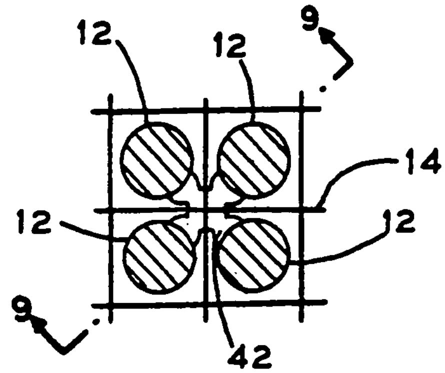
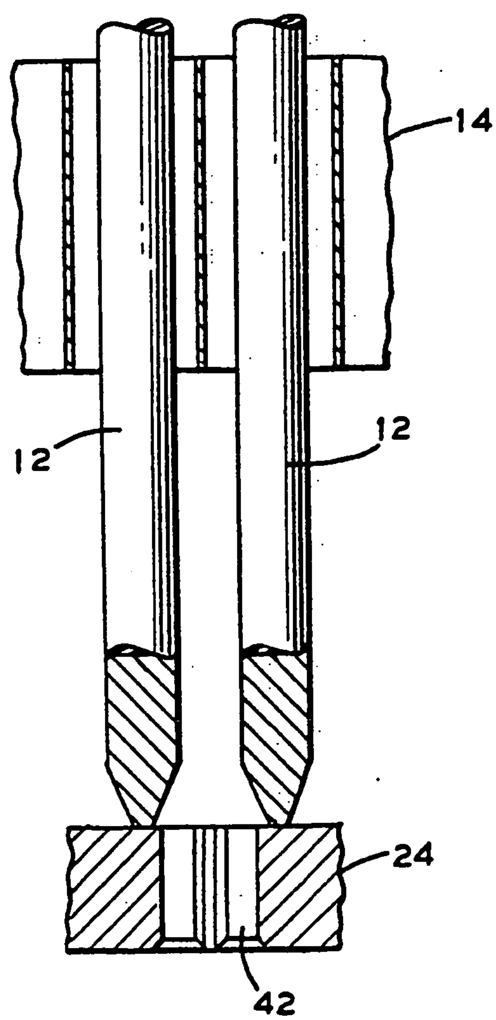



FIG. 9



# NUCLEAR FUEL ASSEMBLY BOTTOM NOZZLE PLATE

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is generally related to a nuclear reactor fuel assembly and in particular to a bottom nozzle plate used with the fuel assembly.

2. General Background

Commercial nuclear reactors include multiple fuel assemblies. Each fuel assembly is comprised of a number of fuel rods radially spaced apart in a parallel array by grid assemblies spaced along the length of the fuel rods. Each grid assembly is formed in an eggcrate design by multiple metal strips that criss-cross at right angles to form individual cells for each of the fuel rods. The strips are provided with tabs that project into the cells against the fuel rods. The tabs serve the purpose of holding the fuel rods in their respective radial position. Control rod guide thimble tubes also extend through selected cells in the grid assembly and are attached at their upper and lower ends respectively to an upper end fitting and a lower end fitting. The upper and lower end fittings are also commonly referred to in the industry as nozzle plates since they are rigid plates that provide structural integrity and load bearing support to the fuel assembly and are provided with flow apertures therethrough for coolant flow. The lower end fitting or nozzle plate is positioned directly above openings in the lower portion of the reactor where coolant flows up into the reactor to the core. The ligaments between apertures in the end fittings coincide with the ends of the fuel rods and limit upward or downward movement of the fuel rods. Debris such as metal particles, chips, and turnings is generated during manufacture, installation, and repair of the reactor, piping, and associated cooling equipment. The size and complexities of the equipment prevent location and removal of all such debris before operations are commenced. Also, some of this debris may not become loose matter in the system until the system is put into operation. It has been recognized that this debris presents a greater problem to the system than previously thought. These small pieces of debris have been found to lodge between the walls of the grid cells and the fuel elements. Movement and vibration of the lodged debris caused by coolant flow results in abrasion and removal of cladding on the fuel rods. This in turn leads to detrimental effects such as corrosion of the fuel rods and failure to retain radioactive fission gas products. Such damage, although not critical to safety of the surrounding environment, can reduce operating efficiency by the need to suspend operation while replacing damaged fuel rods. It can be seen that a need exists for a debris filter capable of filtering debris of a size which may lodge between the grid cell walls and the fuel rods. An important consideration besides that of filtration is that a substantial coolant pressure drop across the filter must be avoided in order to maintain an adequate coolant flow over the fuel rods for heat removal therefrom. Patented approaches to this problem of which applicant is aware include the following.

U.S. Pat. Nos. 4,684,495 and 4,684,496 disclose debris traps formed from a plurality of straps aligned with one another in a crisscross arrangement and defining a plurality of interconnected wall portions which form a multiplicity of small cells each having open opposite ends and a central channel for coolant flow through the trap.

U.S. Pat. No. 4,828,791 discloses a debris resistant bottom nozzle which is a substantially solid plate having cut-out regions in alignment with inlet flow holes in the lower core plate. Separate criss-cross structures fixed to the plate extend across the cut-out regions to act as a debris trap.

U.S. Pat. Nos. 4,664,880 and 4,678,627 disclose debris traps mounted within a bottom nozzle that define a hollow enclosure with an opening so as to form a debris capturing and retaining chamber.

U.S. Pat. No. 4,652,425 discloses a trap for catching debris disposed between the bottom nozzle and the bottom grid. The structure forms multiple hollow cells that receive the fuel rod lower end plugs with dimples in each cell for catching debris carried into the cells by the coolant flow.

U.S. Pat. No. 4,900,507 discloses a nuclear fuel assembly debris filter bottom nozzle formed from a rigid plate having a plurality of flow holes. The holes are individually 0.190±0.008 inch in diameter which is smaller than the predetermined maximum cross-sectional dimension of each of the unoccupied spaces through the lowermost grid. The sections of the plate extending between the flow holes have a maximum dimension of one-tenth inch.

Although a variety of approaches have been taken to the need for filtration of primary coolant, it is felt that the problem has not been adequately addressed. While certain designs such as those utilizing only small flow holes may provide adequate filtration of damaging debris, the problem of an unacceptable pressure drop may still exist.

## SUMMARY OF THE INVENTION

The present assembly addresses the above need in a straightforward manner. What is provided is a nuclear fuel assembly bottom nozzle plate (lower end fitting) having two types of flow holes designed to prevent the passage of damage-inducing debris while minimizing pressure drop of coolant flow across the plate. The bottom nozzle plate serves to support the guide thimbles and fuel rods as well as acting as a filter. The bottom nozzle plate includes legs that support it on the lower core plate. A plurality of flow holes of the first type which are 0.180±0.005 inch in diameter are provided across the plate in groups of four to form square clusters such that the width of the portions or ligaments of the plate between the holes in each cluster is less than the width of the ligaments of the plate between the square clusters. This spacing between square clusters corresponds with the spacing of the fuel rods in the fuel assembly such that the chamfered ends of fuel rods that are allowed to rest on the ligaments of the plate do not block the flow holes. The spacing of holes and number of wider ligaments between clusters is determined by the fuel array, such as a 17×17 or 15×15, that the nozzle plate is to be used with. The second type of flow holes are formed by providing an additional smaller aperture through the nozzle plate substantially at the center of some of the clusters of the first type of flow holes such that the four holes of the original cluster are all interconnected to form an irregular shaped flow hole. The second type of flow holes are positioned so as to be above the core plate holes that pass coolant flow to the nozzle plate when installed in the reactor.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the nature and objects of the present invention reference should be had to the following description taken in conjunction with the accompanying drawings in which like parts are given like reference numerals and, wherein:

FIG. 1 is a partial sectional view of a typical fuel assembly.

FIG. 2 is a side view of the invention.

FIG. 3 is a top view of the invention.

FIG. 4 is a bottom view of the invention.

FIG. 5 is an enlarged view of the second type of flow hole used in the invention.

FIG. 6 is an enlarged view of an alternate embodiment of the second type of flow hole used in the invention.

FIG. 7 is an enlarged cross sectional view of one of the first types of flow holes of the invention.

FIG. 8 is a top view illustrating the relative positioning of fuel rods and the second flow hole.

FIG. 9 is a view taken along the lines 9—9 of FIG. 8.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, FIG. 1 is an illustration of a typical nuclear fuel assembly generally designated by the numeral 10. Fuel assembly 10 is typical of that used in a pressurized water reactor and is generally comprised of a plurality of fuel rods 12, grid assemblies 14, guide tubes 16, upper end fitting 18, and lower end fitting or bottom nozzle plate 20. Fuel rods 12 are maintained in an array spaced apart by grid assemblies 14. Guide tubes 16 extend through grid assemblies 14 and are attached to upper end fitting 18 and bottom nozzle plate 20 and, in addition to providing structural integrity to the entire assembly, also serve as guides for control rods not shown. Upper end fitting 18 and bottom nozzle plate 20 provide structural and load bearing support to fuel assembly 10 and are also provided with openings therethrough to allow coolant to flow vertically through fuel assembly 10. Bottom nozzle plate 20 rests on the lower core support plate (not shown) of the reactor and directly above coolant inlet openings 22 (shown in phantom view in FIG. 3) in the core support plate that direct coolant upward to the fuel assembly. Dimples or tabs in the walls of the grid assemblies 14 radially position the fuel rods to allow maximum surface area contact of fuel rods 12 with the coolant as it flows upwardly therethrough.

Bottom nozzle plate 20, seen in FIG. 2–4, is formed from a rigid substantially square plate 24. Legs 26 may be separate parts attached to plate 24 by any suitable means such as welding or may be integral therewith. Openings 28 provided on two diagonally disposed legs 26 are used to position the bottom nozzle plate 20 with the lower core plate to prevent movement of bottom nozzle plate 20 and fuel assembly 10 during reactor operations. Bottom nozzle plate 20 is provided with two types of holes that do not pass coolant flow therethrough. A plurality of guide thimble tube holes 30 are provided and spaced across the plate in a pattern corresponding to the guide thimble tubes of the fuel assembly. The threaded ends of guide thimble tubes 16 extend through guide thimble tube holes 30 and receive threaded nuts so that the guide thimble tubes are attached to bottom nozzle plate 20. Instrumentation tube hole 32 is substantially at the center of bottom nozzle plate 20 and receives an instrumentation tube used to monitor core conditions during reactor operations.

Two types of coolant flow holes are provided through bottom nozzle plate 20 for passing coolant received from coolant inlet openings 22 in the core plate and for filtering debris of a size known to cause damage to fuel rods 12. A plurality of first flow holes 34 are provided through nozzle plate 20 where each first flow hole 34 is circular in cross section and $0.180\pm0.005$ inch in diameter. As seen in FIG. 3 and 4, the majority of first flow holes 34 are grouped in clusters of four holes arranged to define a square pattern 35 relative to the sides of nozzle plate 20. This provides an arrangement of flow holes where the width of the sections or ligaments of the plate between flow holes within the cluster is less than the width of the ligaments of the plate between the clusters. The narrower ligaments within the clusters are indicated by the numeral 36 while the wider ligaments between clusters are indicated by the numeral 38. In the preferred embodiment, the spacing of flow holes 34 to define square clusters 35 is determined by the number of fuel rods 12 in the fuel assembly above bottom nozzle plate 20. For example, in a $17\times17$ array such as that illustrated, the number of square clusters is arranged so as to provide 15 wider ligaments 38 across bottom nozzle plate 20 in addition to the boundary ligaments. In this manner, the end of fuel rod 12 contacts bottom nozzle plate 20 at wider ligament 38. This provides stable support to the fuel rod and more importantly does not result in any of the flow holes being blocked by the fuel rod which would cause a pressure drop and reduction of coolant flow. On a projected basis fuel rods 12 do overlap the holes, however the rods are chamfered at the lower end to prevent direct blockage. This is best seen in FIG. 8 and 9. As seen in the cross sectional view of FIG. 7, each of first flow holes 34 is provided with a chamfered lower edge 40. As indicated by the letter A, the angle of chamfered lower edge 40 is 45 degrees plus or minus 2 degrees. This provides a diameter of $0.216\pm0.008$ inch (as indicated by the letter B) at lower edge 40 in the preferred embodiment. The chamfer decreases the hydraulic resistance of coolant flow through the flow holes and thus reduces the pressure drop of coolant flow. As seen in the drawings, the presence of guide thimble tube holes 30 and instrumentation tube hole 32 prevent all of first flow holes 34 from being arranged in groups of four. In order to maintain structural integrity of bottom nozzle plate 20 around holes 30 and 32, it is necessary to eliminate one of first holes 34 in each group around holes 30 and 32 to prevent overlap of holes.

A plurality of a second type of flow holes 42 are preferably positioned so as to be above the coolant inlet openings 22 in the core plate when bottom nozzle plate 20 is in its installed position. As best seen in FIG. 5, each of second flow holes 42 is an irregular shaped hole that may be described as a modification of the four first flow holes 34 in square pattern 35 to define a substantially clover leaf shape in top or bottom view. The modification to obtain second flow hole 42 comprises interconecting the four flow holes in the square pattern. This is accomplished by removing a section of bottom nozzle plate 20 that is centrally located between the four flow holes such that an equal amount of each flow hole in the pattern is included by the removed section. In the preferred embodiment, central portion 44 of each second flow hole 42 defines a square having its corners intersect the four flow holes of the square pattern. As indicated

by the letter C in FIG. 5, the extended distance along a plane from the center of central portion 44 to the center of each of the four holes originally forming the square pattern is 0.1125 inch in the preferred embodiment. As indicated by the letter D, the width of central portion 44 is 0.117 inch. As indicated by the letter E, each corner of central portion 44 intersects a width of 0.025±0.015 inch of each of the four flow holes originally forming the square pattern. The channel width E of 0.025 inch is chosen to be less than the nominal spacing of 0.041 inch between bottom nozzle plates in the reactor core. This insures that the most open passage for debris to enter the fuel rod region is not through the flow holes that lead directly to the spaces between the fuel rods and grid assemblies that are more likely to trap damaging debris. In the preferred embodiment, second flow holes 42 are located on bottom nozzle plate 20 so as to be evenly distributed over all coolant inlet openings 22 in the core plate. For a 17×17 array such as that illustrated, there are a total of sixteen second flow holes 42, four above each coolant inlet opening 22 in the core plate. This provides a flow area of 8.47 square inches above coolant inlet openings 22 in the core plate.

In addition to minimizing pressure drop of coolant flow, the number and positioning of second flow holes 42 are also selected so as not to have a detrimental effect on the structural integrity of bottom nozzle plate 20. The structural loads that act on bottom nozzle plate 20 during operations are transmitted through the guide thimble tubes and fuel rods 12 and are reacted out at legs 26. Due to the large number of load points (24 guide thimble tubes and 264 fuel rods in a 17×17 array), bottom nozzle plate 20 behaves as a uniformly loaded plate fixed at the corners. Under these loading conditions the maximum stresses occur near the center of the plate and near the fixed boundary. Second flow holes 42 are located midway between these areas in a generally low stressed area of nozzle plate 20.

An alternate embodiment of second flow hole 42 is illustrated in FIG. 6 and indicated by the numeral 142. Central portion 144 is circular instead of square and is 0.142 inch in diameter. This provides a flow area of 8.52 square inches above coolant inlet openings 22 in the core plate. Dimensions C and E are the same as for second flow hole 42.

In operation, bottom nozzle plate 20 supports fuel assembly 10 by means of guide thimble tubes 16 attached through guide thimble tube holes 30. Bottom nozzle plate 20 is positioned on the core plate by dowels extending through openings 28 in legs 26. First and second flow holes 34,42 are sized and spaced apart so as to filter damage inducing debris from the coolant while minimizing the pressure drop of coolant flow. For a 17×17 array fuel assembly, square plate 24 measures 8.425 inch along each side and is 0.637 inch thick. The thickness of the plate is required to maintain structural integrity as it supports the fuel assembly and is subject to the pressures of coolant flow. The spacing of flow holes in square clusters 35 provides ligaments 38 between square clusters that are 0.090 inch and ligaments 36 between holes in the square clusters that are 0.045 inch. After allowing sufficient space for guide thimble tube holes 30 and instrumentation tube hole 32, this provides eight-hundred sixty first flow holes 34 and sixteen second flow holes 42 for a total of eight-hundred seventy-six flow holes. For the standard square plate used in a 17×17 array as mentioned above, this provides a flow hole density of approximately 12.34 holes per square inch. Naturally, the number of flow holes will vary in direct proportion to the size of the bottom nozzle plate used with the flow hole size and spacing taught herein.

Because many varying and differing embodiments may be made within the scope of the inventive concept herein taught and because many modifications may be made in the embodiment herein detailed in accordance with the descriptive requirement of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in a limiting sense.

What is claimed as invention is:

1. In a fuel assembly for a nuclear reactor, a bottom nozzle plate having legs adapted to be positioned on the lower core plate of the reactor for supporting the fuel assembly above coolant inlet openings in the core plate, said bottom nozzle plate comprising:

a. a rigid substantially square plate; and

b. said square plate having a plurality of first coolant flow holes therethrough where each of said first flow holes is circular in cross section and 0.180±0.005 inch in diameter with the majority of said first flow holes grouped in clusters of four to define a square pattern relative to the sides of said square plate such that the width of the sections of said square plate between said first flow holes in said square pattern is less than the width of the sections of said square plate between said clusters of four holes and said square plate having a plurality of second coolant flow holes therethrough positioned so as to be above the coolant inlet openings in the core plate when said bottom nozzle plate is installed in the reactor, with each of said second flow holes being of an irregular pattern to define a substantially clover leaf shape.

2. The bottom nozzle plate of claim 1, wherein each of said first flow holes has an inlet chamfer of 45 degrees plus or minus 2 degrees.

3. The bottom nozzle plate of claim 1, wherein the width of the sections of said square plate between said first flow holes in said square pattern is approximately 0.045 inch and the width of the sections of said square plate between said clusters of four holes is approximately 0.090 inch.

4. In a fuel assembly for a nuclear reactor, a bottom nozzle plate having legs adapted to be positioned on the lower core plate of the reactor for supporting the fuel assembly above coolant inlet openings in the core plate, said bottom nozzle plate comprising:

a. a rigid substantially square plate; and

b. said square plate having a plurality of first coolant flow holes therethrough where each of said first flow holes is circular in cross section, has an inlet chamfer of 45 degrees plus or minus 2 degrees, and is 0.180±0.005 inch in diameter with the majority of said first flow holes grouped in clusters of four to define a square pattern relative to the sides of said square plate such that the width of the sections of said square plate between said first flow holes in said square pattern is approximately 0.045 inch and the width of the sections of said square plate between said clusters of four holes is approximately 0.090 inch and said square plate having a plurality of second coolant flow holes therethrough positioned so as to be above the coolant inlet openings in the core plate when said bottom nozzle plate is installed in the reactor, with each of said second flow holes being of an irregular pattern to define a substantially clover leaf shape.

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